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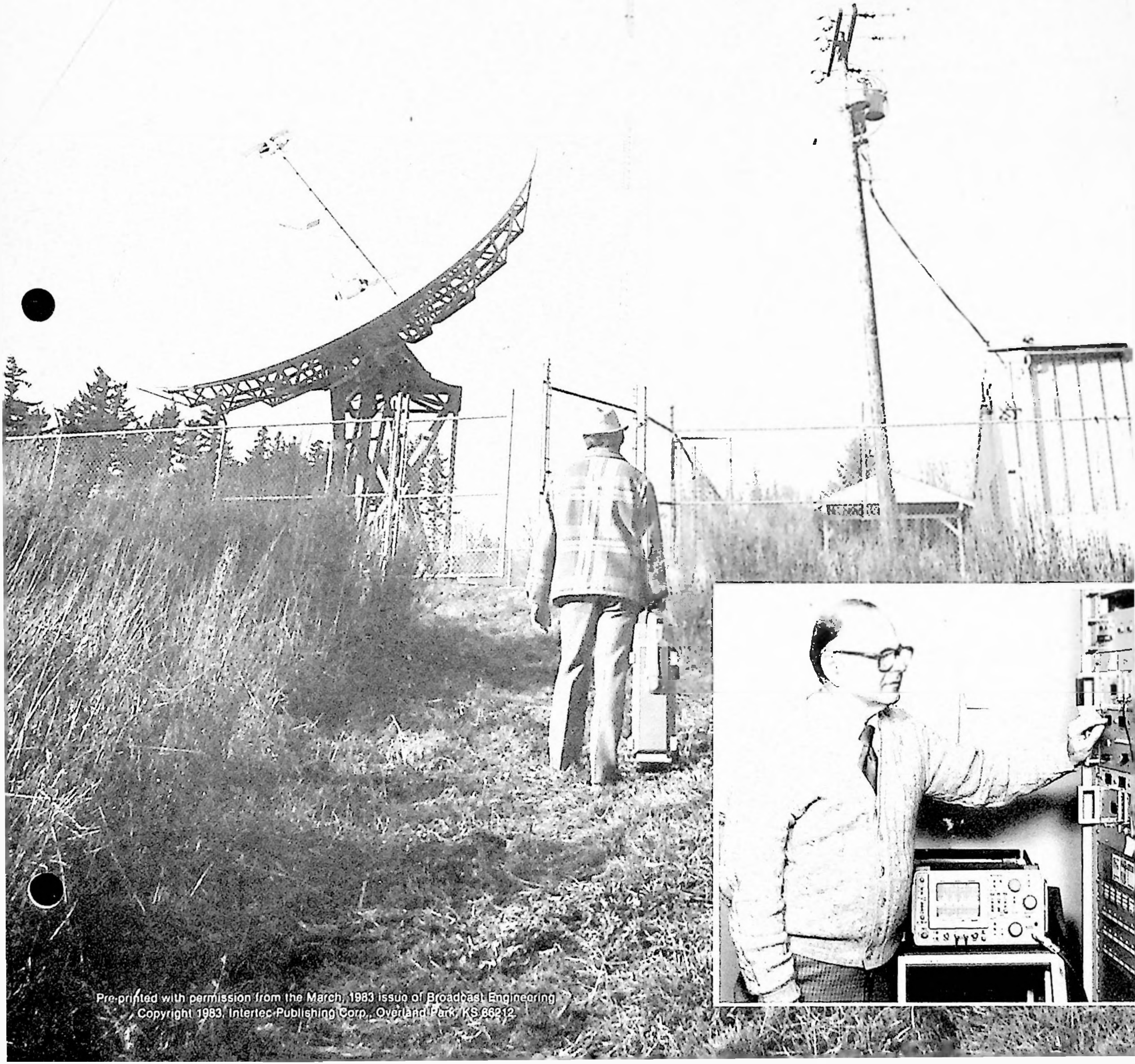
"THE SPECTRUM ANALYZER AND THE EARTH STATION"

By Archie Brusch, Assistant
Chief Engineer, KATU (TV), Portland, Oregon



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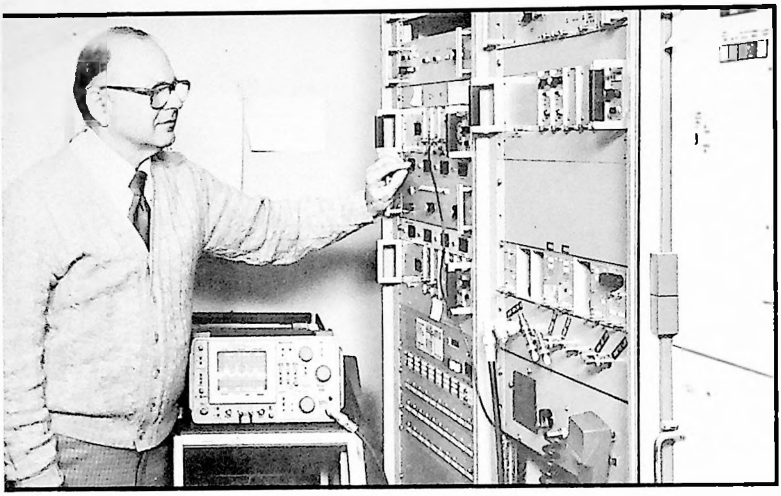
The spectrum analyzer and the earth station


The author, checking out part of KATU's installation.

By Archie F. Brusch, assistant chief engineer, KATU-TV, Portland, OR

It has been my good fortune the past several years to act as project director for the installation of the earth station at KATU-TV, Fisher Broadcasting, Portland, OR. As one of the first to use a remotely controlled dish for a downlink, KATU also pioneered the use of uplinking directly to satellites, being the first TV station in the Northwestern United States to have both transmitting and receiving facilities serving the TV broadcast video needs of the area.

The success of this installation has been phenomenal. Some 200 *uplinks* have been handled through the KATU facility. Because KATU offers the only uplink operation in the region, there has been a great demand for the service. Transmissions via satellites have been furnished to many organizations, including the following: ABC, CBS, NBC, ESPN, CNN, SNC, ITNA, Westinghouse and other Portland stations. Special feeds have been furnished as well to San Francisco, Los Angeles, Atlanta, Denver, New York, Hawaii, Alaska and numerous other places. The principal uses of uplinks are for news, sporting events, *Mount St. Helens* activities and other happenings of national interest. The downlinks are used several times daily by KATU for receiving various programs. Also downlinks can serve other stations in the Northwest by special network interconnects.

Installing, operating and maintaining the 10m Scientific-Atlanta dish antenna, the receiving equipment and the 3kW 6GHz high power amplifier has provided both rewarding and tense moments. During the transition in at last becoming *professional satellite communicators*, there has been (from an engineering standpoint) one bright spot in our array of test equipment: our spectrum analyzer, the Tektronix 492.

Routine use, service and maintenance of equipment used to access the geostationary satellite system is greatly facilitated by the presence of this dominant test instrument. An instrument such as the 492 is essential in siting the antenna; performing system tests on low noise amplifiers (LNAs) and receivers; identifying the transponders on the many satellites; locating the satellites themselves; uplinking; aligning downlinks; accurately determining antenna polarization; locating and determining interference levels; and performing the required power measurements when illuminating the transponders.

Locating a usable site

The authorized bandwidth of the downlink frequencies used (from 23,000 miles in space to earth) is about 500MHz and extends from 3700MHz to 4200MHz on 24 individual channels, beginning with 3720MHz and stepping in 20MHz separations to 4180MHz. (This is generally referred to as the 4GHz receive band.)

Because of limited spectrum space, a tremendous amount of activity is found in the 4GHz terrestrial service band generated by point-to-point microwave paths. The band is used by many services, primarily telephone companies. The point to be made here is that *interference* is a real problem in the 4GHz band. Terrestrial and space-to-earth transmissions will be seen as interference. Therefore, when siting an antenna for minimum interference, the services of reliable frequency coordination research companies such as Comsearch, Compucon or others are usually obtained. Basically, the companies proceed by accomplishing two things.

First, they plot all known sources of emission geographically, showing the proposed site in the center of the plot. Information on frequency, ERP, decibel losses, obstruction losses and orientation of antennas involved, patterns of antennas involved, etc., are fed into a computer. Charts are generated to show all sources that will interfere at the proposed location, along with the expected interference level in dBm and type of modulations.

Second, they visually confirm the

Acknowledgement
The preparation of this article and the success of this earth station project would not have been possible without the assistance and cooperation of William Vandermay, manager, engineering, KATU.

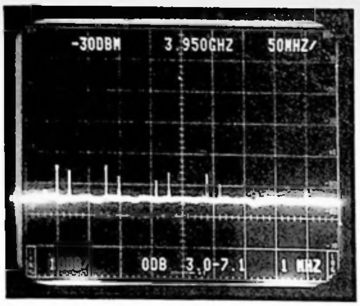


Figure 1. Interfering signals arriving at approximately −74dBm and −77dBm.

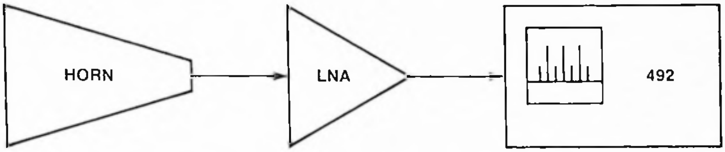


Figure 2. Block diagram of the equipment used in the site analysis.

results of the computer search by observing each interfering signal on the spectrum analyzer. This is done using a microwave horn antenna feeding an LNA of known gain that establishes the maximum *measurement system* sensitivity in decibels. The signals at the output of the LNA must be detected and identified as to level and individual frequency. This is most conveniently done by using the Tek 492 or similar instrument as the detector and visual display device.

The Tek 492 spectrum analyzer is an instrument of considerable internal complexity coupled with a front panel set of controls that allows simple, down-to-earth operator control. It makes an almost impossible job easy.

Several functions of the Tek 492 are of particular interest to the broadcast engineer. The capability for displaying a *spectrum* of RF signals visually with 5MHz accuracy in the microwave region is probably most important. Not only does it display the band of signals of interest, the Tek 492 screen also shows, at a glance, the dBm level of any of the many signals displayed. The push of a button on the front panel can change it from 10dB/div. to 2dB/div. and resolve amplitude differences in 0.25dB steps, when necessary.

When searching for a site, the controls are set to display 50MHz/div. (horizontally) so that the entire 500MHz band will be displayed. Center frequency should be set to 3950MHz with the attenuation controls adjusted to make the top display line read out at -30dBm.

Using the gain in decibels of the horn antenna plus the LNA gain, you now are able to read an incoming signal's dBm level from the front panel display. In Figure 1, the interfering signals are arriving at the 492 at approximately −74dBm and −77dBm. If you subtract the gain of your antenna and LNA system, you have the actual dBm level of the interfering signal. By comparing this to the calculated interference level from the initial paper survey computer-generated chart, you may: (a) validate the chart data; (b) discover any field variations that can be used to your advantage; and (c) discover field variations that are detrimental.

Directional characteristics of the horn antenna and the readout of dBm level of the 492 enable you to discover paths and usable obstructions on the terrain between your site and the source of interference. The antenna is used to slowly *scan* the horizon a full 360° in azimuth, first using vertical polarity, then horizontal.

Photographs may be easily taken for documentation and study. Because both the antenna and spectrum analyzer are portable, all that is needed is a source of power and the LNA. This verification search is usually performed between midnight and local sunrise when conditions are optimal. Figure 2 is a block diagram of the equipment used in the site analysis.

We have used the Tek 492 several times to identify frequency and azimuth of interfering signals as well as modulation type. In one situation, a neighboring station about 200 feet higher in elevation was experiencing strong interference to one of its downlink feeds. By using the station's 7m dish and built-in LNA, with the 492 as a detector/visual display, we were able to pinpoint the azimuth and type of interference. Needless to say, the narrower the interfering signal, the easier it will be to trap out with minimum damage to your own received signal from the satellite.

Servicing microwave receivers

Servicing downconverters is greatly simplified with the 492 because, basically, you must measure dBm level and frequency of the PLL output of the incoming RF signal and their resulting mix. Should there be any spurious products generated, they can be seen at once. By following the IF frequency from the downconverter through the IF system, proper level buildup and proper band shaping can readily be observed on the 492. Outputs of LNAs, photographed and placed in the maintenance log, can serve as reminders of what the normal sky noise and beacon strengths are, thus checking the LNA for proper operation or showing need of repairs/maintenance.

The use of the proper waveguide/N-type adapter, combined with the portability of the 492, makes direct observation and measurements at the antenna feedhorn output possible.

Locating satellites using the 492

If you use the Tek 492 to locate transponders, or even satellites, keep in mind that on satellites using only 12 channels, all transponders will be peaked on horizontal polarity. These will all null out with a 90° rotation of the feedhorn in either direction. On newer satellites using 24 channels, the odd channels will be of one polarity and the even channels will be 90° away. Figure 3 is a photograph of such a satellite with one polarity nulled out.

To maximize visibility of the individual transponders on a search for a satellite, the optimal position of the feedhorn would be half way between the two polarities, or 45° away from

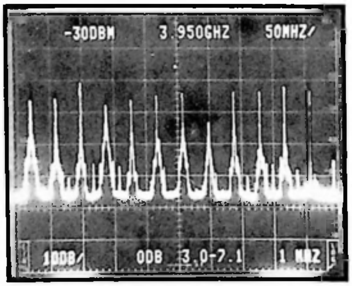


Figure 3. The newer satellites, with one polarity nulled out.

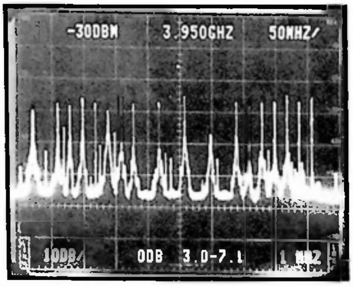


Figure 4. Optimized position of the feedhorn makes all active transponders visible.

any null condition. This will make all 24 transponders visible, providing that they are active, and at least will maximize your chances of seeing one or two if the satellite is not busy at that time. Figure 4 shows such a *maximized* condition.

At 10° to 15° (in either direction) from proper polarization of the received downlink signal, a fairly decent and clean picture will still show on your monitor. However, in the uplink mode, you *must* be as close to optimal polarization as possible.

Some typical questions

Why not just use the video monitor to help locate the bird or the transponder?

There are two major reasons for use of the Tek 492 instead of the video monitor. First, you would have to know which transponders were active so that you could tune the receiver to that frequency in order to display any received video. With the Tek 492, you are *by-passing* the entire receiver and its tuning mechanism, making all 24 channels visible at one time. Second, it is almost impossible to satisfactorily orient the polarization using only the video (picture) monitor. With the spectrum analyzer, it becomes a simple procedure to *null* every odd visible transponder. Once a proper null is obtained on *any* set of transponders (or beacon), odd or even, you have all the polarization information needed. The opposite polarity is always 90° away. Many of the new feed systems have instant polarity changeover, using multiple ports.

But what if no signals are on the satellite; all transponders inactive? Then how do we locate the target, and how can we set polarization?

This can be done by searching for the *beacons* that are located at approximately 4199MHz on each Westar satellite or 3700.5MHz on Satcom and Comstar satellites. Beacons are always present on the satellites, and occasionally are the only signals present. A beacon consists of two small CW signals, closely spaced at about one-third the amplitude of a normal transponder signal. Figure 5 shows a beacon in the presence of three received transponder signals.

Note that the beacon appears to be just one signal when first located. However, adjusting the resolution and expanding the frequency displayed per horizontal division, as shown in Figure 6, separates the beacon into two signals that are stable and can be used either as a *locator* or as a null-out signal for polarity setting. The 492, serving as a wideband receiver, is sampling the output of the LNA in Figures 5 and 6 through a resistive splitter. This splitter also feeds the actual receiver in the system.

The rough search for satellites is

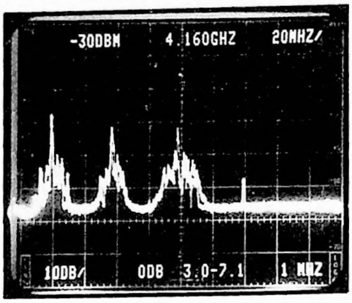


Figure 5. A beacon (right) in the presence of three transponder signals, at about one-third of their amplitude.

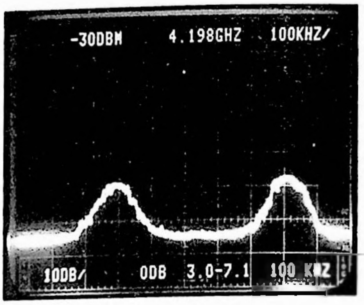


Figure 6. The beacon signal can be separated and used as a locator or for a null-out signal.

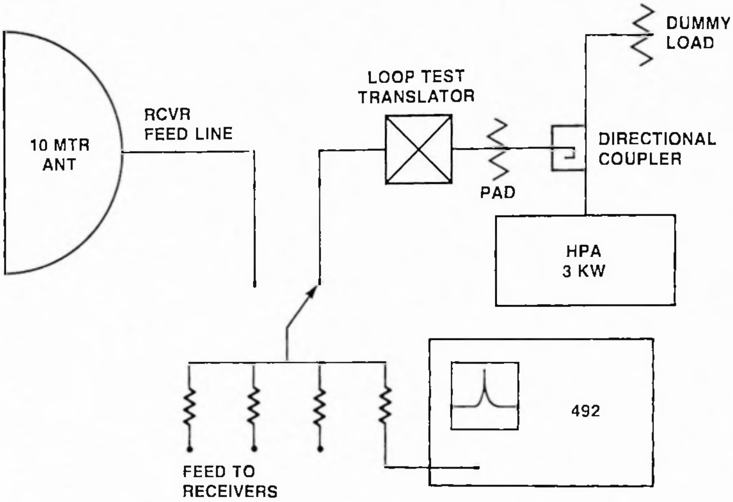


Figure 7. Observing the signal through a *loop test translator.*

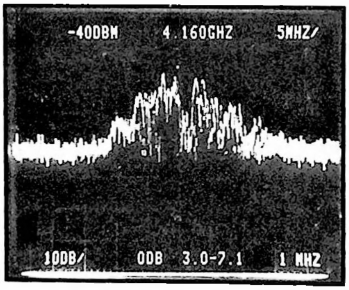


Figure 8(a). Depressing *maximum hold* builds up a solid pattern showing channel occupancy.

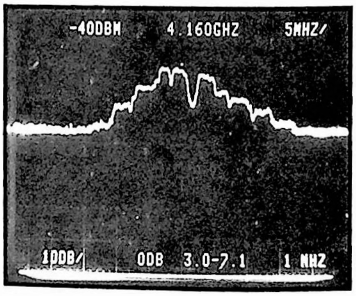


Figure 8(b). A quick computation pinpoints whether or not you are spilling over the ± 18MHz deviation area.

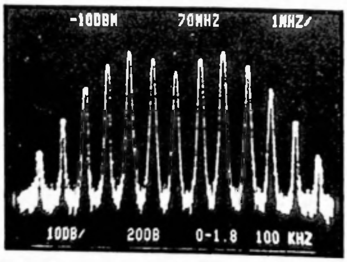


Figure 9(a).

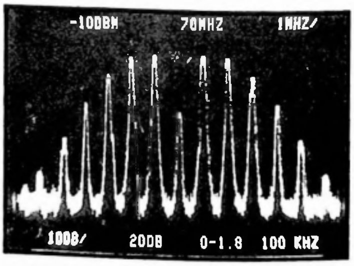


Figure 9(b).

done by setting the azimuth and elevation to the published *look angle*, placing polarization 45° off normal and carefully tweaking azimuth and vertical until you spot the beacon (or a transponder). A normal signal from a transponder at the KATU location (approximately the 45th parallel on the Pacific Coast), is about +30dB above noise level, which is about −60dBm at output of the LNA. For the beacon, it is only about +10dB above noise level. Final touchup is done using the receiver system's carrier/carrier plus noise meter on a live transponder.

Uplinking measurements

In uplinking (transmitting), we need a fast, easy method of checking for occupancy (deviation) for 100% modulation. This is achieved using the Tek 492 with the *frequency span-per-division* set for 5MHz, *center frequency* set to observe the incoming channel in the 4GHz band and *attenuation* set for easy viewing of our received signal, as observed through a *loop test translator*, shown in Figure 7.

With the transmitter operating normally into its dummy load, a sample is taken through a directional coupler from the power amplifier output. This 6GHz sample is routed to a superheterodyne-type mixer, called a loop test translator, which treats the sampled 6GHz signal as a real transponder would. The 6GHz transmitter signal is heterodyned down to the 4GHz band and the signal routed to the receiver system and to the spectrum analyzer. We could observe the same thing by sampling directly with the 492 at the output of the directional coupler, viewing it directly at 6GHz.

With a full-field color bar signal being transmitted as in Figure 8(a), if we now depress *maximum hold* on the 492, the display rapidly builds a solid pattern showing occupancy of the channel. In Figure 8(b), if you count up the horizontal divisions and multiply by 5MHz, you can see at a glance whether you are spilling over your ±18MHz deviation area. A full 36MHz width is normal for 100% modulation. This is a quick, easy check.

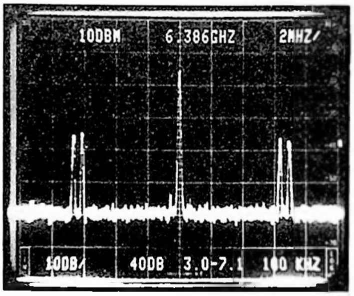


Figure 10(a).

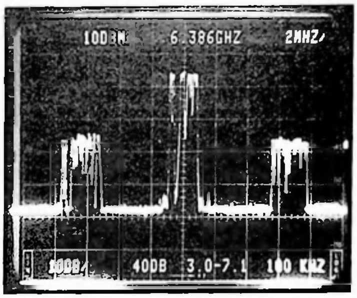


Figure (10(b).

Figures 10(a) and 10(b) show the effect of dispersal. In Figure 10(a) the main carrier and two audio subcarriers are viewed with dispersal *off*. In Figure 10(b), with dispersal *on*, the waveform jitters.

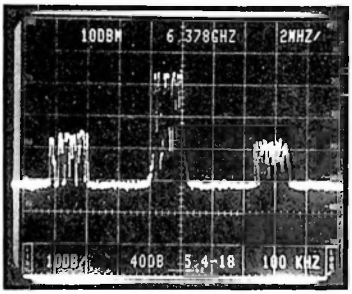


Figure 11. Measuring the dispersal signal, with *maximum hold* depressed about one second.

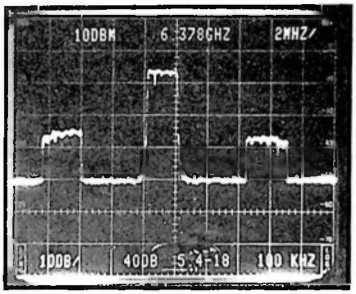


Figure 12. Measuring the dispersal signal, with *maximum hold* depressed several seconds.

During the earth station transmitter installation, and yearly performance checks, the Tek 492 should be used to set modulation level at precisely 100%. The manufacturer will inform you of the video frequency to use and the absolute level input to the modulator, and will identify the proper takeoff point. At this takeoff point the Tek 492 will see, typically, a 70MHz intermediate frequency signal or other modulated signal. (The white dot in Figures 9(a), 9(b), 9(c) and 9(d) identifies center frequency.)

Figures 9(a)-9(d) are a series showing the nulling of the 70MHz carrier, as the deviation (modulation) control is adjusted on the modulator. In the case of the Scientific-Atlanta modulator model 461WB, the injection frequency is 0.7616MHz at an exact level of −20.68dBm. The deviation control is carefully adjusted for the complete disappearance of the 70MHz IF signal at the first null. This coincides with a typical video signal containing 100 IRE units of white and 40 IRE units of sync pulse, for peak-to-peak video of 1V.

When measuring carrier power, as displayed on the Tek 492, turn off the *dispersal* control. Figure 10(a) represents the main carrier, plus two audio subcarriers, viewed with *dispersal* off. Figure 10(b) shows why you must turn the *dispersal* off to obtain a stable waveform; with *dispersal* on, the waveform jitters.

Dispersal is applied to the carrier and sidebands to protect the transponder by dispersing the energy content of the signal illuminating it. In the absence of modulation (video), the dispersal unit sweeps the entire signal back and forth over a 2MHz wide sweep at the rate of 30Hz. If sync is applied as video, the dispersal drops to about 1MHz.

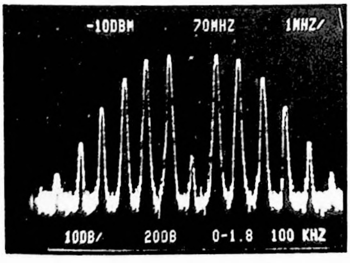


Figure 9(c).

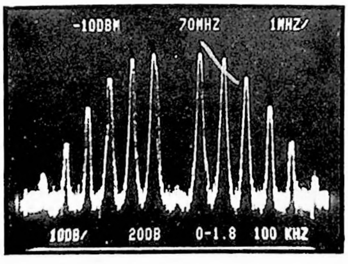


Figure 9(d).

Figures 9(a)-9(d) are a series that shows the nulling of the 70MHz carrier (in this case) as the deviation (modulation) control is adjusted on the monitor.

Figure 11 illustrates the difficulty in measuring the dispersal signal. It is taken with the *maximum hold* button depressed about one second before opening the camera shutter. Should you wish to measure the actual dispersal deviation, hold the *maximum hold* button down for several seconds (Figure 12) so that you can measure (roughly) just short of 2MHz deviation.

A more accurate measurement of deviation of the main carrier is shown in Figure 13 with each horizontal division representing 0.5MHz. The 3.8 divisions multiplied by 0.5 equals 1.9MHz.

In Figure 10(b), it appears, at first glance, that the two subcarriers are being deviated too much. However, there are two of them, and they merge into one large, indistinct pattern. This method of measuring dispersal deviation of a carrier is only valid if one separate carrier or subcarrier can be separated on the analyzer.

If we remove all modulation and dispersion so that our carrier is reduced to a CW carrier—with the aural subcarriers at 6.2MHz and 6.8MHz—we will be able to use the 492 as an accurate power meter. Figure 14 shows a block diagram of a typical earth station uplink system including power amplifier, directional coupler for sampling the signal as it is delivered into the waveguide, and the 10m dish. In this case, the 492 is sampling the waveform and reading the power directly in dBm.

Figure 15 shows the top of the main carrier touching the top graticule line, which is labeled as – 6dBm.

Now, we tabulate known losses:

Loss in directional coupler = – 36.1dB
Loss in fixed pad = – 20dB
Loss in coax between 492 = – 9.9dB
Total losses = – 66dB.

With a reading of – 6dBm, and known losses of – 66dB, there must be 60dBm at the amplifier output. This is 1000W of carrier.

In calculating the effective radiated power(ERP) of the dish, we start out with + 60dBm at the input to our waveguide feed line. There is 3dB loss in the feed system, leaving + 57dBm arriving at the feedhorn. The antenna is rated at 53.5dBi gain, so the center of the radiated beam, as observed from a point far out in space, will be 110.5dBm, which is slightly more than 100,000,000W of power.

Two practical achievements are involved in the previous discussion: First, we can arrive at the dBm output for proper illumination of the transponders by considering the total space losses to and from the satellite, the dB gain of the receiver and LNA, our system losses and the safety margin desired. Second, we can also use the information to accurately set the front panel wattmeter on the Klystron amplifier to read 1kW output. Obviously, if we were interested in calibrating the meter exactly at, say, 260W (a practical level), we could do that also. All without leaving the security of the dummy load and the convenience of the Tek 492! (If these numbers seem large, please note that the 2-way path loss is in the order of 200dB!)

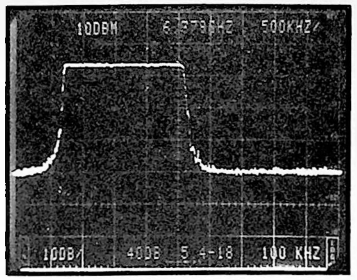
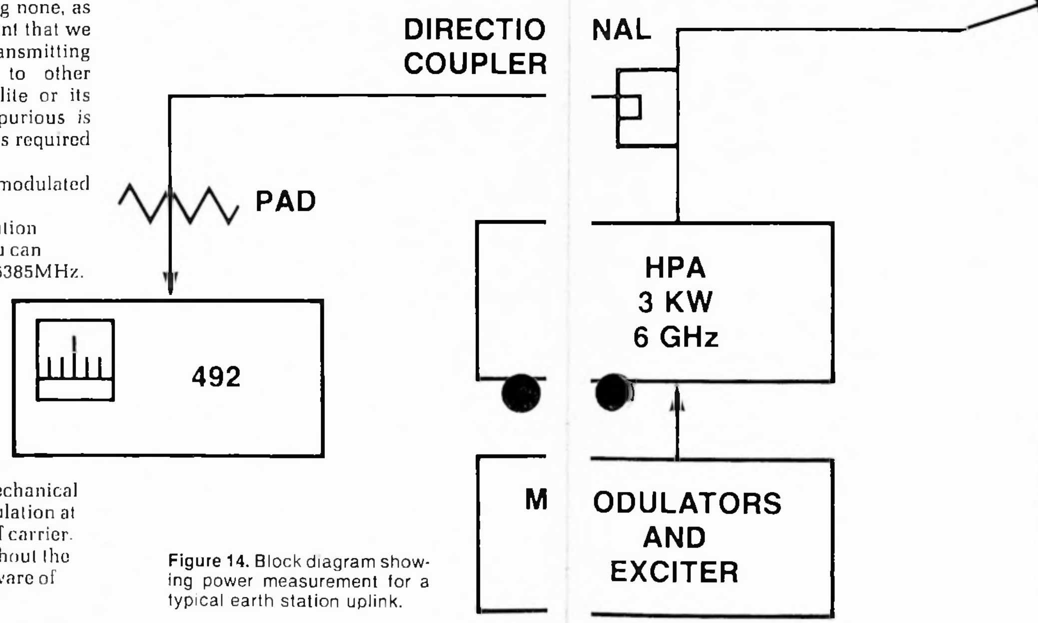


Figure 13. A more accurate measurement of deviation of the main carrier.

While the Tek 492 is sampling the power amplifier output, we should take a look at the surrounding base line at least up to and including 12GHz, to detect the presence of any type of spurious emission or intermodulation products. Seeing none, as in Figure 16, we are confident that we will not be asked to cease transmitting for causing interference to other transponders on this satellite or its neighbors. If something spurious is seen, then remedial action is required at once.

By expanding the unmodulated signal with the frequency span-per-division and resolution controls, as in Figure 17, you can observe the main carrier at 6385MHz. The noise of the base line is down about 55dB from peak-of-carrier. However, note the disturbance about 40dB down on the carrier itself. Expanding this as in Figure 18, you observe what is probably mechanical noise giving some AM modulation at about 600kHz from center of carrier. This could be fan noise. Without the Tek 492, we would not be aware of such items of interest.



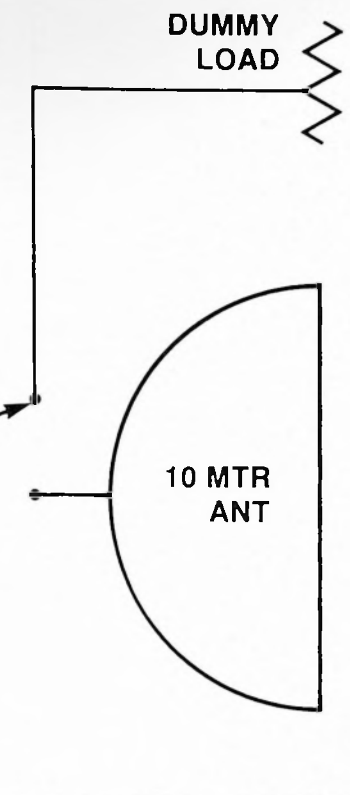


Figure 14. Block diagram showing power measurement for a typical earth station uplink.

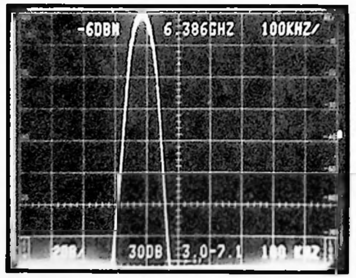


Figure 15. The peak of the main carrier touches the top graticule, labeled at – 6dBm.

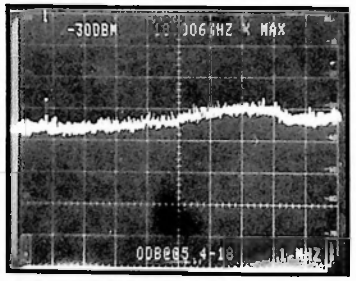


Figure 16. Checking the base line to detect presence of any spurious emission or intermodulation products.

Sweeping the Klystron amplifier

Our particular Klystron has 12 cavities that must be tuned to 12 preselected transponder channels. Sweeping these cavities is a chore because the average station does not have the proper equipment. Leasing equipment is one answer, but takes several days to a week before you can set up.

With the Tek 492 in the station and a good microwave sweep generator, you can do an acceptable job of sweeping individual cavities, using the *Save A* and *Max hold* functions with a moderate sweep rate.

First, record the signature of the cables and fittings involved by feeding the sweeper directly into the spectrum analyzer through those cables. Capture this trace with *Save A* near the top of the screen (use 10dB/div. at first). Then, inject about + 5dBm of sweep into input of amplifier under test, with amplifier running into dummy load, and run one swept cable from the 492 input to the directional coupler takeoff point at output of the amplifier. Adjust trace to be lower on screen than that you saved at *A*. (See Figure 19.)

Adjust for usable sweep rate and you will be able to do major surgery to the waveform by adjusting the cavity controls. When you have the lower trace as close as possible to the top (*Save A*) trace, the cavity will be usable at that frequency.

For final adjustment, switch the 492 to *2dB/div. log* for an expanded view of each cavity in band ripple.

Figure 20 (upper trace) is a swept display of cables and connectors only in the 2dB/div. expanded log mode. The lower trace is a swept response display of one cavity before final adjustment.

With a little patience, frequency response measurements may be made to + 0.5dB using this procedure.

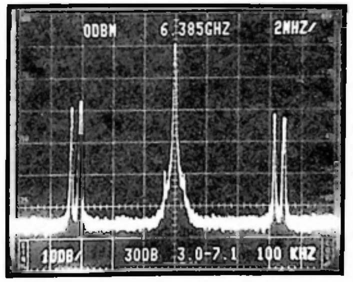


Figure 17. Expanding the unmodulated signal to observe the main carrier at 6385MHz.

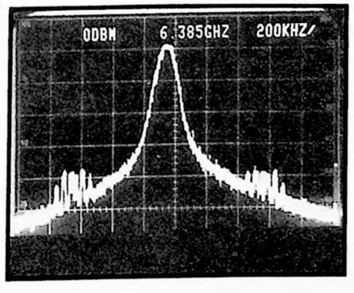


Figure 18. Expanding the carrier shows what is probably mechanical noise giving some AM modulation at about 600kHz from center of carrier.

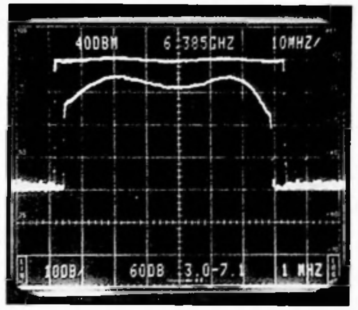


Figure 19. Swept frequency response of cables and fittings (upper trace) end cavity including cables (lower trace) in *10dB/div.* log vertical mode.

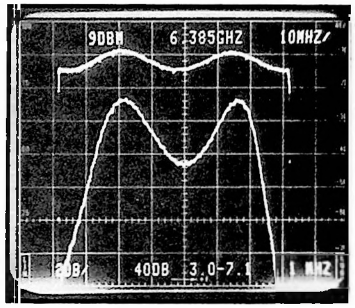


Figure 20. Swept frequency response in *2dB/div.* vertical log mode. Upper trace shows cables and fittings only. Lower trace includes cavity.

Summary

I have presented some practical uses of the Tek 492 as used in our earth station facilities at KATU. The capability of the instrument for displaying and measuring dBm over a wide frequency range; displaying same on the screen for off-the-screen measurements should, by now, have stirred your imagination to other uses. By combining a good low capacity probe designed to feed a 50Ω input, such as the Tektronix P-6056/P-6057 or equivalent, with the 492 instrument, you can use it directly in microwave circuitry and intermediate frequency amplifiers of any bandwidth. Distortions, spurious emissions and intermodulation products can be seen, for the first time, on the service bench.

For further information in the U.S.A., Asia, Australia, Central America, South America and Japan, contact Tektronix, Inc., P.O. Box 500, Beaverton, Oregon 97077. Phone: 800/547-1512. Oregon only 800/452-1877. In Europe, Africa and the Middle East, contact Tektronix Europe B.V., Postbox 827, 1180 AV Amstelveen, The Netherlands. Phone: (20)471146. In Canada, contact Tektronix Canada Inc., P.O. Box 6500, Barrie, Ontario L4M 4V3. Phone 705/737-2700.

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