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LOW NOISE MEASUREMENTS IN AN RF ENVIRONMENT

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13. ABSTRACT (Maximum 200 words)

This report describes a problem that is often ignored when making radiated noise measurements. The measurements in this report are secondary to the "cleaning up" of the total spectrum before any measurements can be made of a selected bandwidth.

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LOW NOISE MEASUREMENTS IN AN RF ENVIRONMENT

1. INTRODUCTION

This report describes a recent VHF noise measurement that was performed in support of a meteor burst evaluation program. It highlights a pitfall that may occur if one were to make electromagnetic noise measurements over a limited spectrum when the measurement equipment is functional over a much wider spectrum.

2. PURPOSE

The purpose of this measurement was to determine the electromagnetic noise environment at the Rome Laboratory's Verona Research Facility in order to determine the suitability of using this site to evaluate antenna array techniques that might apply to meteor burst communications. The spectrum of interest was 40-43 MHz; however, it was later noted that a much larger spectrum must be examined.

3. DISCUSSION

It is often convenient to use a spectrum analyzer to study a range of frequencies to determine if there are any objectionable signals that might cause interference. The noise figure of most spectrum analyzers, however, is so poor (typically about 20-30 dB) that they must be used in conjunction with a low noise preamplifier. While a spectrum analyzer might have a rather large linear dynamic range, this cannot be expected of a low noise amplifier. Therefore, care must be taken not to overdrive the amplifier, even at frequencies out of the displayed spectrum or phantom signals and noise may appear in the frequency band of interest due to nonlinear mixing of out of band signals. First, the amplifier must be examined to determine what level of signal is required to raise the level of the nonlinear products above its noise floor. Then, when initially making noise measurements, it is necessary to examine the entire range of frequencies to which the amplifier may respond so that any high level out of band signals may be limited by appropriate filtering. The same consideration must also be given to the spectrum analyzer itself because it may be driven into its nonlinear range and further restrict the maximum signal allowed at the input of the preamplifier.

There are two types of noise to be concerned with, interferers and broadband noise. The interferers, which are other transmitters in the vicinity, will generally be very sporadic and have a finite bandwidth and their signal level is measured in terms of power. The broadband noise, generally a combination of galactic noise and manmade noise, will be distributed in frequency and is measured in terms of spectral power density. When using an HP-8562A spectrum analyzer as the measurement receiver, the marker can be toggled to read either the absolute magnitude of an interferer or to read the spectral power density, using an averaging technique to measure the broadband noise. One must be careful to use the proper marker setting when making such measurements since erroneous results may be obtained when trying to measure discrete signals in terms of power density.

4. AMPLIFIER CHARACTERIZATION

The preamplifier used for these measurements was an ENI-500-L which has a typical noise figure of 8 dB and a maximum output power of 300 milliwatts over a frequency range of .5 MHz to 500 MHz. In order to keep the nonlinear products of extraneous signals down to the noise amplifier floor, it is necessary to limit all input signals to the amplifier to about -40 dBm. This was determined by exciting the broadband amplifier at the lower end of its frequency response and observing the level of the harmonics. Figure 1 shows that the second harmonic, the largest of the nonlinear products, of a 40 MHz signal is suppressed to the noise level of the amplifier, measured over a 10 KHz bandwidth, with the applied signal level less than -40 dBm. Under these conditions, all nonlinear products are better than 7 dB below the expected galactic noise level (about 15 dB above thermal).

5. INITIAL MEASUREMENTS

For the purpose of identifying any signals between .5 MHz and 500 MHz that may drive the preamplifier hard enough to produce objectionable nonlinear products, the spectrum analyzer, with no preselection filters, was connected to a dipole that was resonate in the 40-43 MHz band of interest. This initial measurement identified three types of interfering signals with signal strengths above -40 dBm, AM, FM and television broadcasting stations as shown in Figure 2. The discrete levels were not recorded because the level of the signals was high enough to drive the spectrum analyzer to saturation and produce erroneous results. As a result of these initial measurements, preselection filters were designed to limit all signals into the preamplifier to less than -40 dBm.

6. FILTER DESIGN

An off-the-shelf 50 MHz low pass filter, with the loss vs frequency response, shown in Figure 3, was used to suppress the FM stations and marginally suppress the television station. A coaxial stub filter was designed and fabricated for a bandpass response as shown in Figure 4. The response of the combination of both filters is shown in Figure 5. When these two filters were incorporated in the measurement system, all of the interfering signals to the input of the amplifier were suppressed to less than -40 dBm. The amplifier was then included in the

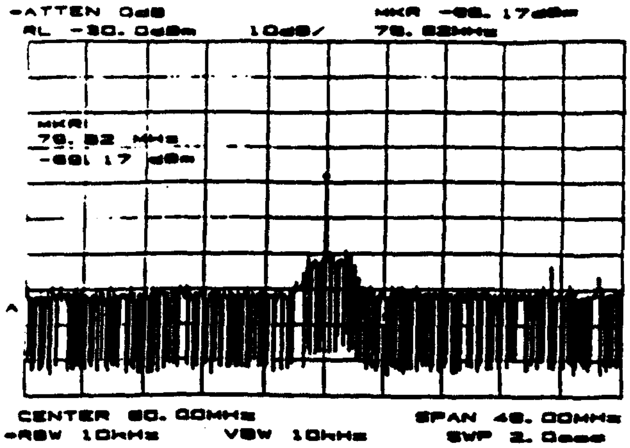

Figure 1a Second Harmonic of a 40 Mhz Signal With a Level of -30 dbm

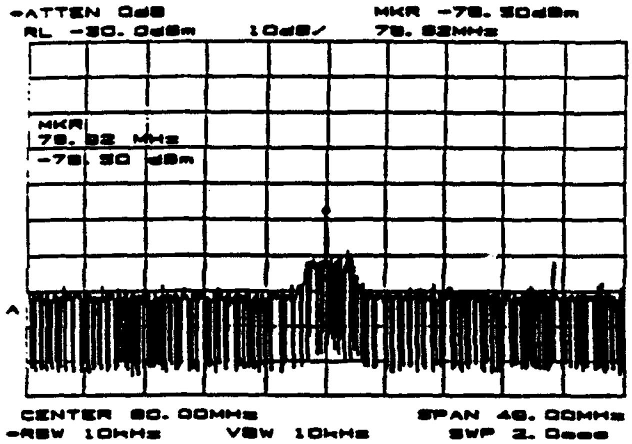

Figure 1b Second Harmonic of a 40 Mhz Signal With a Level of -35 dbm

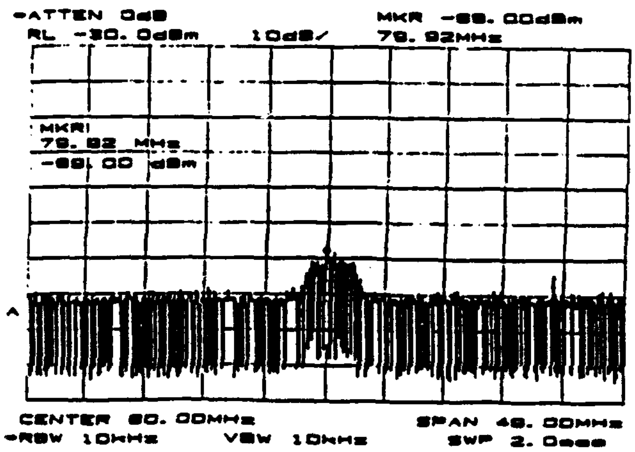

Figure 1c Second Harmonic of a 40 Mhz Signal With a Level of -40 dbm

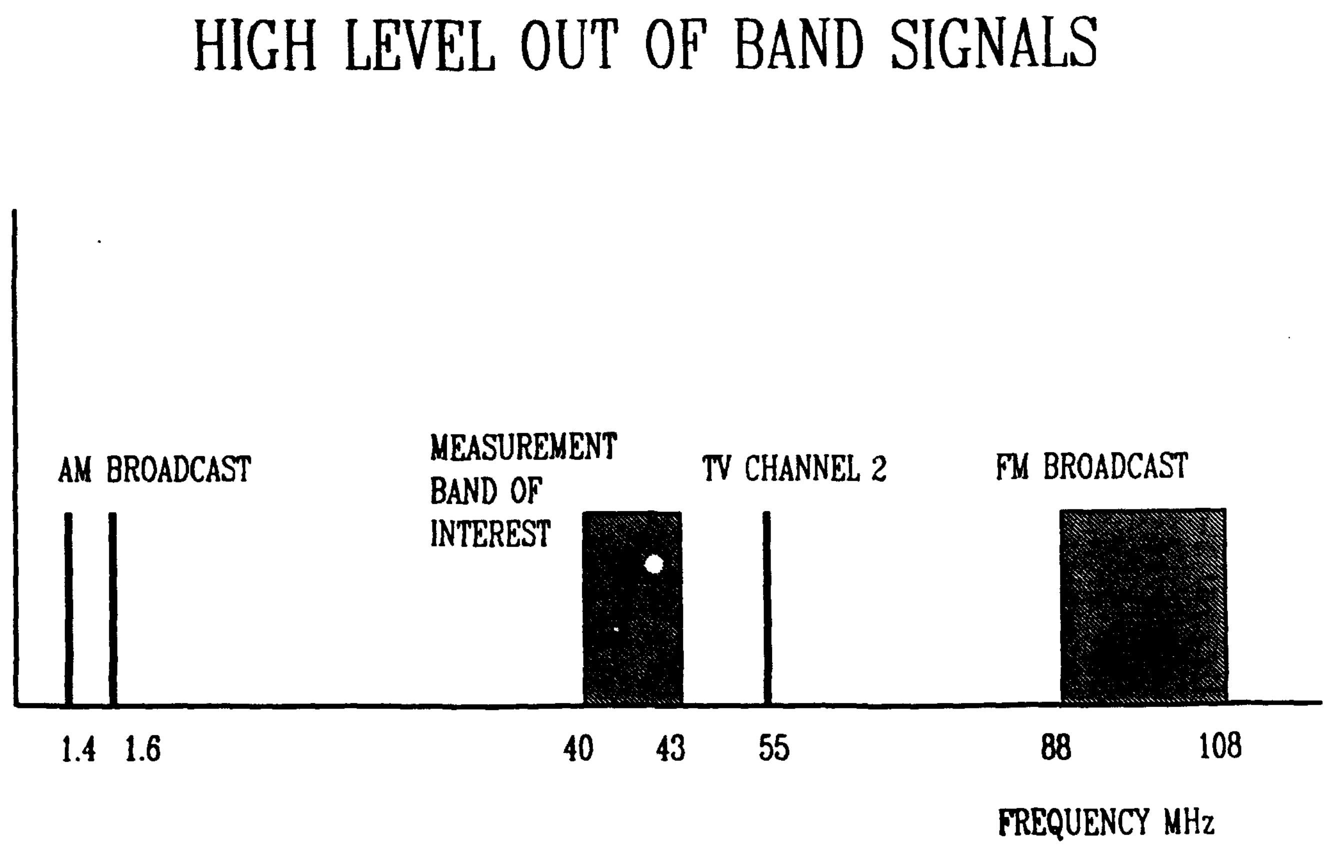

Figure 2 Major Sources of Interference

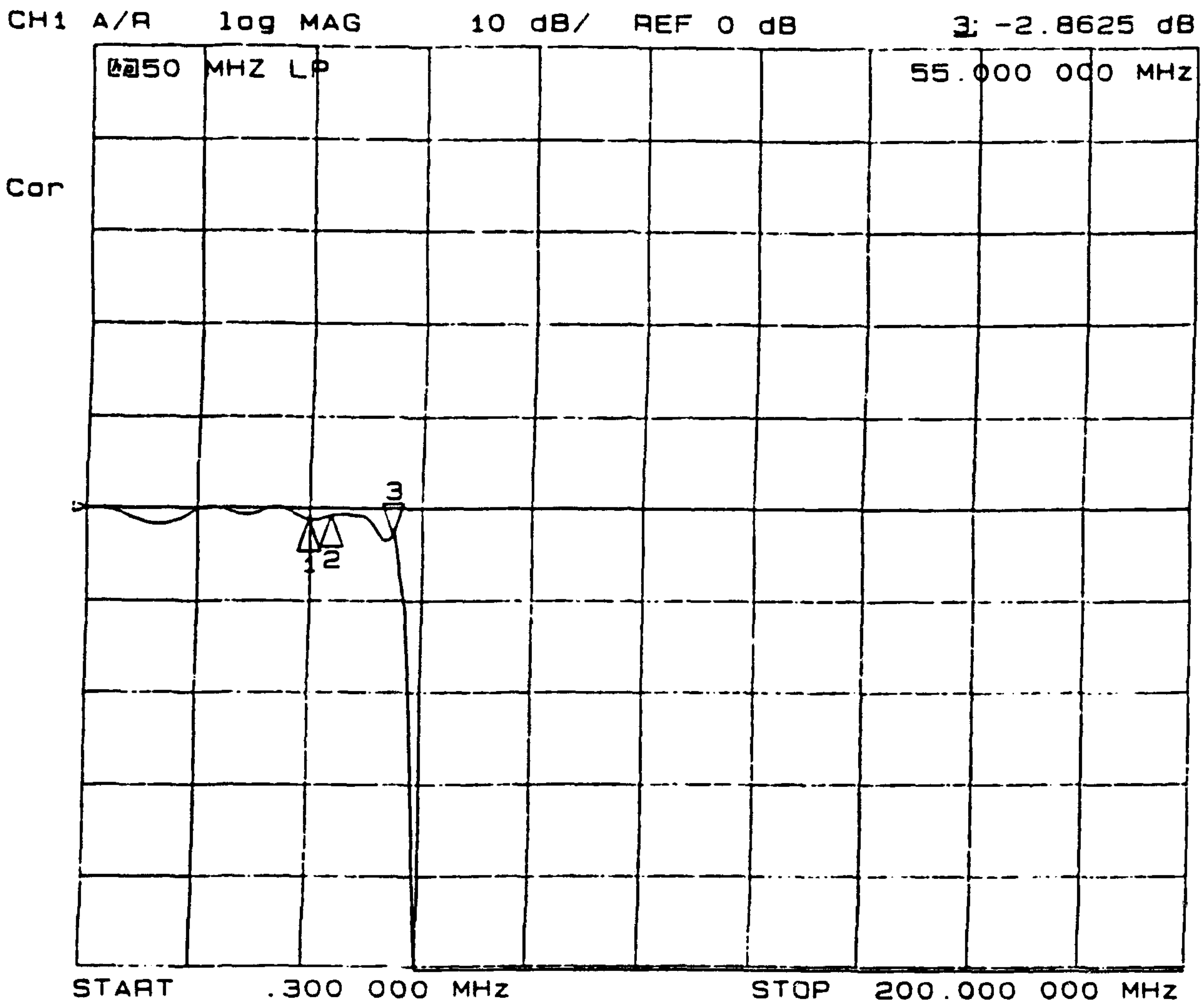

Figure 3 Response of 50mhz low pass filter

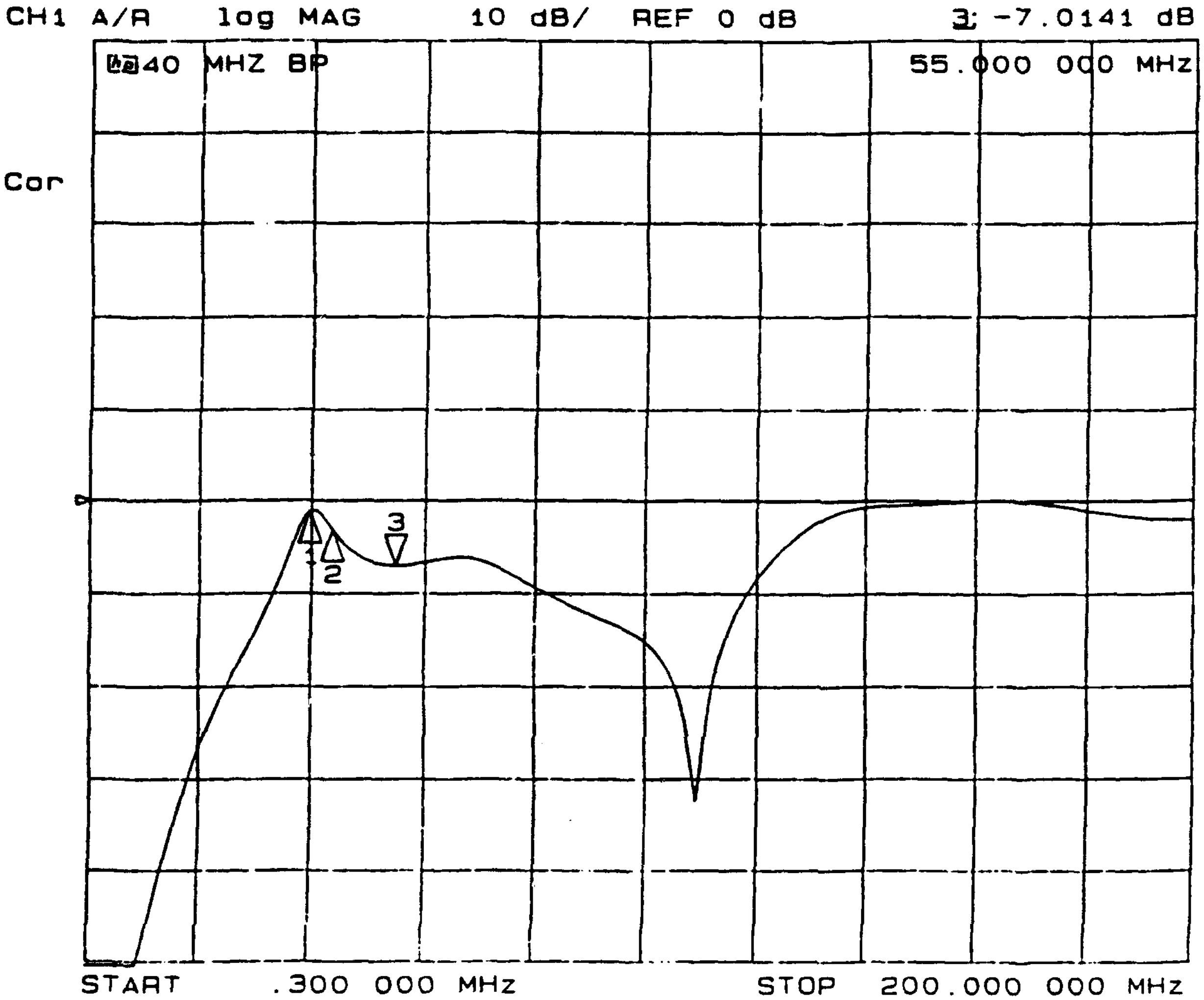

Figure 4 Response of band pass stub filter

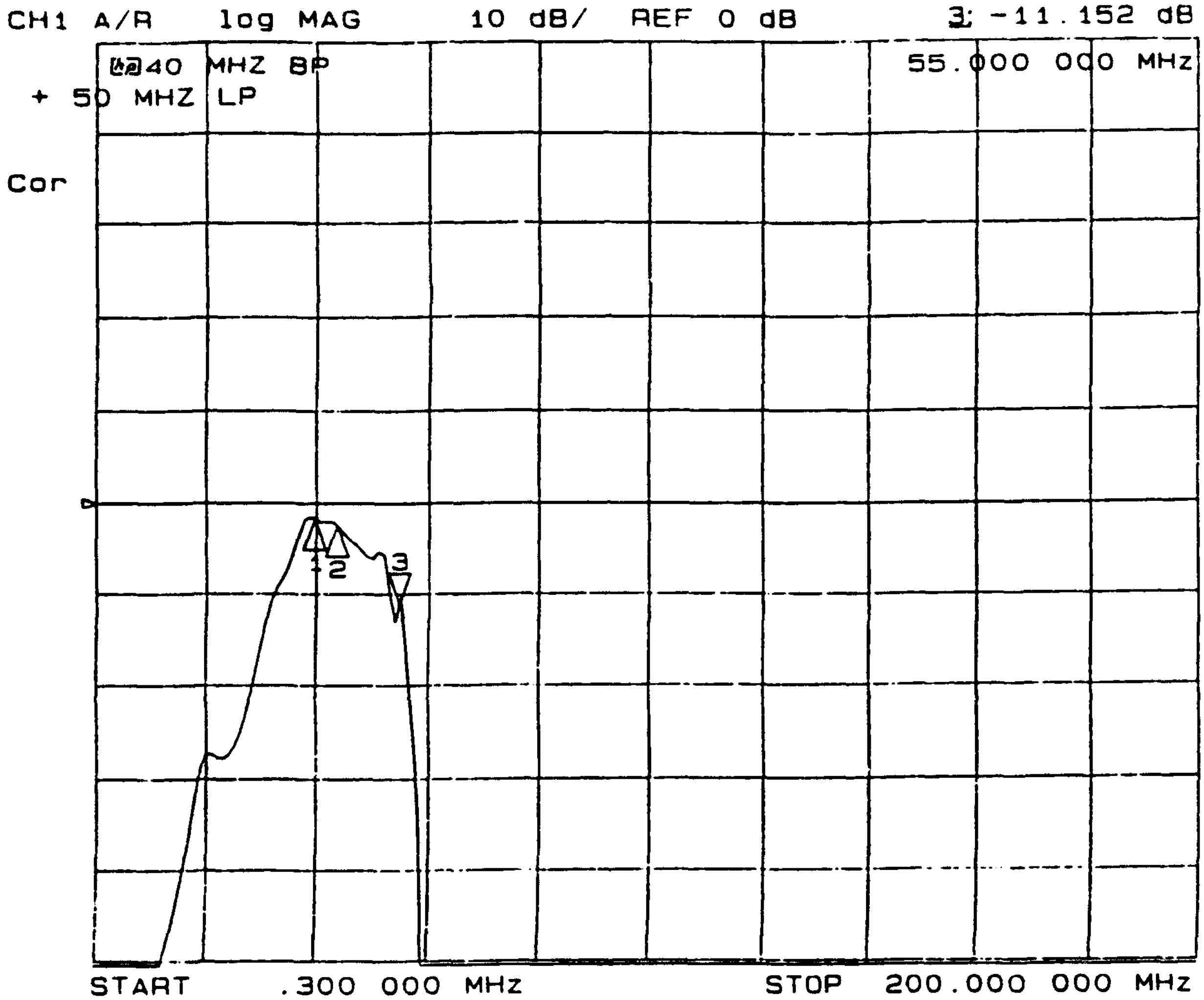

Figure 5 Response of both filters

measurement configuration depicted by the block diagram in Figure 6. As a check, the spectrum analyzer was scanned from .5 MHz to 500 MHz to insure that there were no signals passed by the amplifier and filters to the spectrum analyzer that would exceed the -20 dB limit at which the analyzer becomes excessively nonlinear.

7. CALIBRATION

The amplitude measurements displayed on the spectrum analyzer were corrected to account for the amplifier gain of 27 dB, about 2 dB insertion loss in the pass band of the filters and about 2 dB insertion loss of the 60 foot of RG-58 transmission line as shown in Figure 7.

8. FINAL NOISE MEASUREMENTS RESULTS

Several measurements were made at Verona on different days and different times of the day. Two typical noise measurements are shown in Figures 8 and 9 where several traces were made on each graph. Figure 8 identifies typical discrete interferers, measured in dBm, and Figure 9 defines the broadband noise as a power density measurement in terms of dBm/Hz. After applying the calibration factors to account for amplifier gain and insertion loss, the broadband noise at this site referenced to the antenna terminals, was typically -154 dBm/Hz. This is about 5 dB above the expected level of -159 dBm/Hz for galactic noise at these frequencies. It must be emphasized that this is typical data as there was considerable variation of the number and the intensity of the discrete interferers. The broadband noise, however, was more consistent over time.

BLOCK DIAGRAM VHF NOISE MEASUREMENT

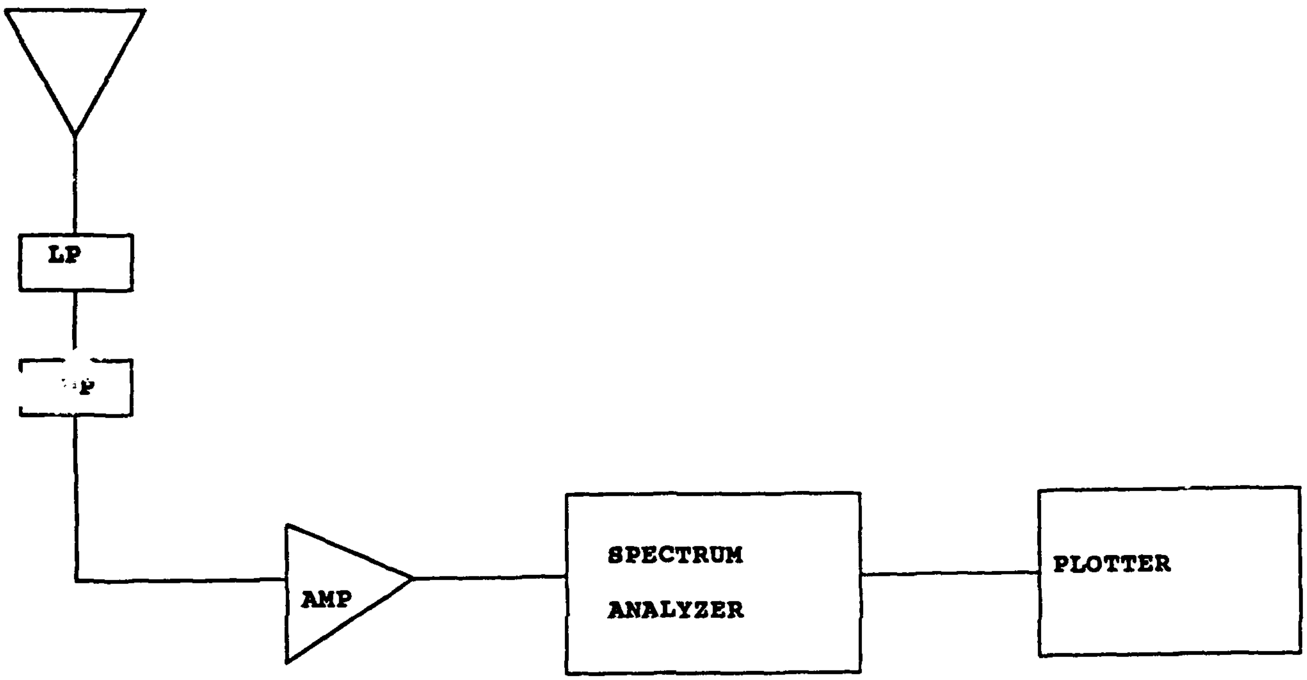

Figure 6 Block diagram of measurement system

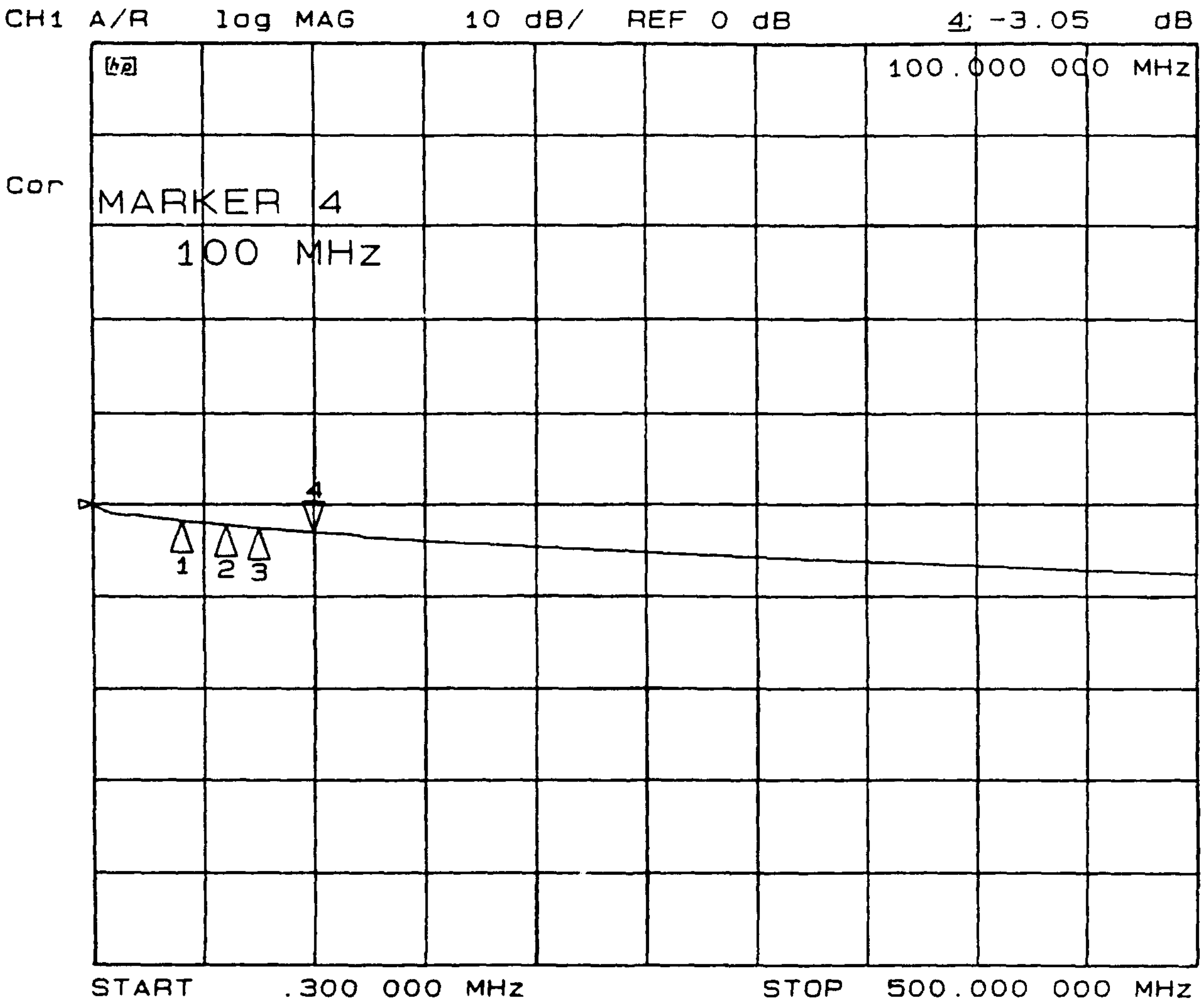

Figure 7 Insertion loss of 60 ft. of RG-58 coaxial cable

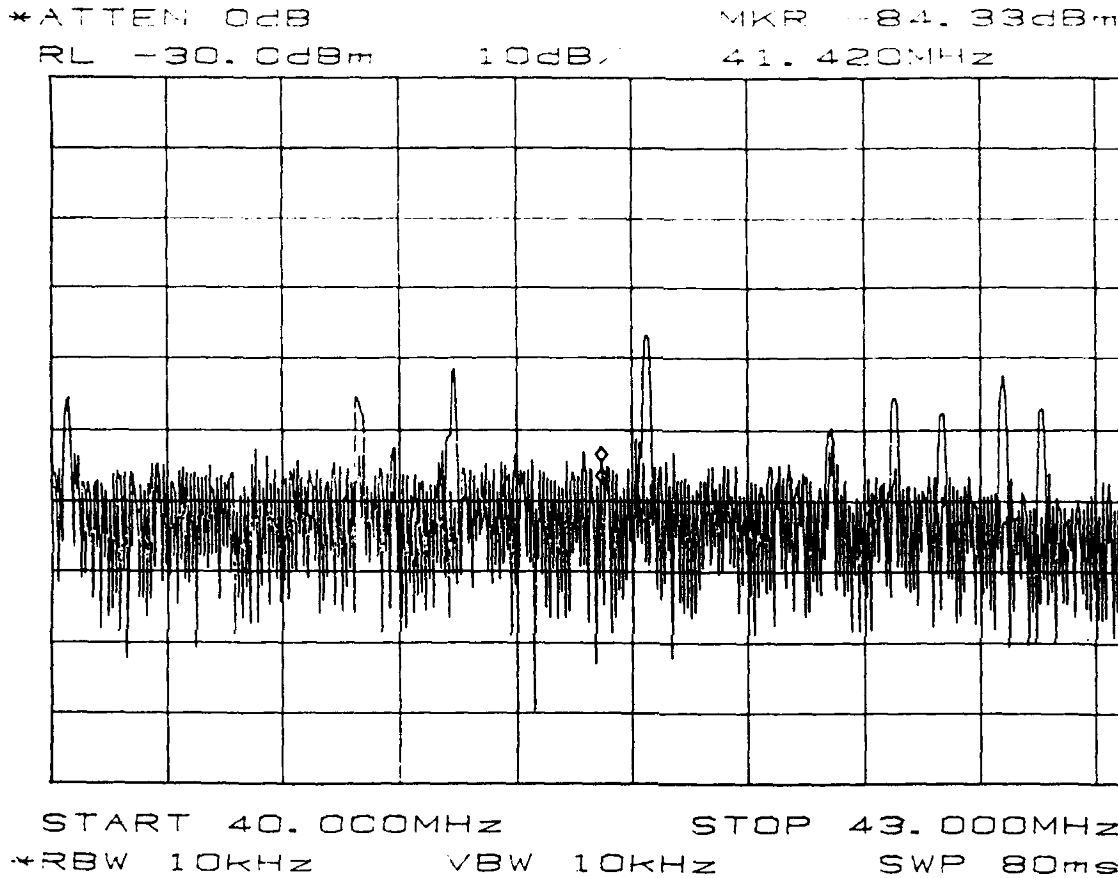

Figure 8 Typical measurement of discrete signals
(Note marker reads dbm.)

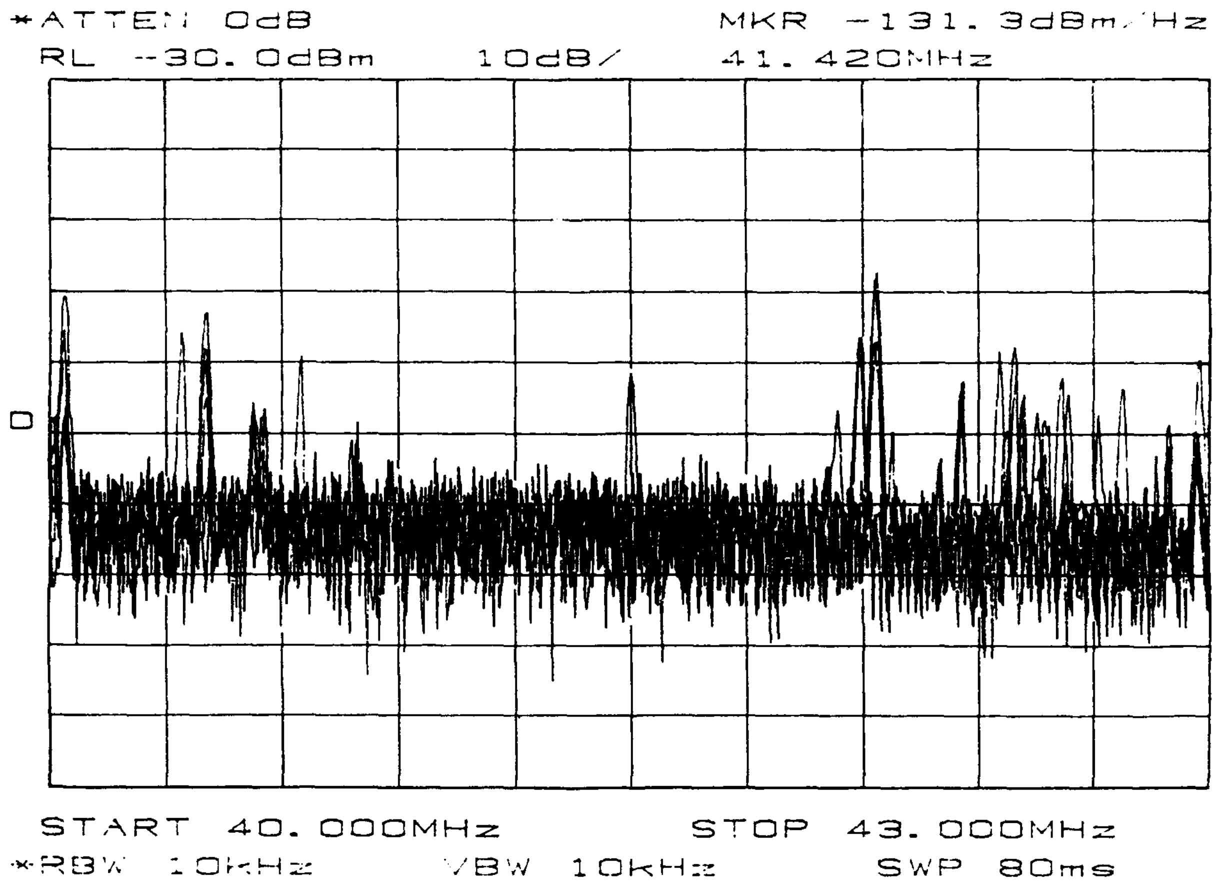

Figure 9 Typical measurement of broadband noise
(Note marker reads dbm/Hz)

9. CONCLUSION

In order to be certain that one has made accurate noise measurements of radiated fields, the entire frequency spectrum to which the measurement equipment will respond must be examined. Also, the equipment must be operating in a suitably linear range so that the nonlinear products do not raise the noise floor at the frequencies to be measured. In order to be within this linear range, the amplifier will be operating well below its maximum power output; in this case, about 60 dB below the 1 dB saturation point. Only after it has been determined that all equipment is operating in a suitably linear range, the spectrum may be narrowed to include only the frequencies of interest.

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