EMI/RFI test receivers

Specialized receivers demand tighter design requirements

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Many electrical devices – from computers to hair dryers – generate electrical noise. This noise is either conducted along power cables to other electrical devices, or radiated through the unit's enclosure, keyboard, or screen to the world outside, thereby producing interference that affects still other electrical instruments.

A receiver able to detect and measure this interference and relate it to precise (accepted) international standards must necessarily be based upon a different design than that of a communications receiver. The latter type normally covers the 10 kHz to 1000 MHz frequency range and is primarily designed to receive and decode selected transmissions. Conversely, an EMI receiver must include the following design features:

A greater instantaneous dynamic range than that of a communications receiver, since the energy of incoming pulses can be higher than several intelligence-bearing signals or constant carriers

A circuit that monitors the maximum allowable voltage at different stages, to prevent short-term overload

Detector time constants that conform to internationally agreed-upon standards

Appropriate IF bandwidths

Precise amplitude calibration over the operating frequency range (Attainment of this normally requires the use of either a spectrum generator or tracking generator.)

If active antennas are used to measure the field in the low frequency range, they must have the *necessary dynamic range and proper antenna correction factor*.

The different requirements of test receivers and normal communications receivers will be discussed in this article, with special attention paid to the relative advantages or disadvantages of manual and automatic measuring capability.

dynamic requirements

Before specific EMI/RFI receivers – such as the Rohde & Schwartz ESH2 manually-operated

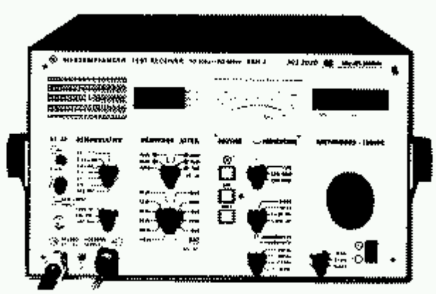

fig. 1. Manually operated EMI/RFI test receiver, type ESH. Frequency range, 10 kHz to 30 MHz.

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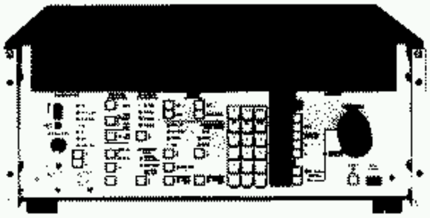

fig. 2. Microprocessor-controlled EMI/RFI test receiver, type ESH3, features built-in intelligence. Frequency range, 10 kHz to 30 MHz.

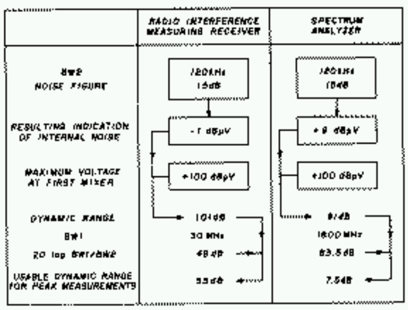

fig. 3. Comparison of EMI/RFI receiver and spectrum analyzer to evaluate usable dynamic range.

EMI/RFI 10 kHz to 30 MHz receiver (**fig. 1**) or the ESH3 computer-controllable EMI/RFI test receiver with built-in intelligence (**fig. 2**) — were introduced, spectrum analyzers were generally used to detect and characterize emitted noise spectrums. There has been some controversy as to whether spectrum analyzers that employ special "quasi-peak" detectors (CISPR/ANSI) can provide the necessary information. This is an important issue and should be clarified.[1]

The spectrum analyzer, while quite capable of rapidly providing data on CW and various sinusoidal signals, is not as suited to measure pulse spectrum parameters with the same facility. To understand why, a discussion on spectrum and bandwidth requirements is called for.

Electrical pulses of short duration possess considerable energy over a wide frequency range. When this signal is introduced into a bandpass filter, the output peak voltage (of the pulse) is proportional to the pulse bandwidth (which is approximately the 6 dB bandwidth of the filter).

$$E_{peak} \propto BW\ (6\ dB) \qquad (1)$$

If a signal having a pulse spectrum is introduced into two cascaded bandpass filters with different bandwidths, $BW1$ and $BW2$ (with $BW1 > BW2$), the ratio of the output peak voltage is equal to the ratio of the filter bandwidths or:

$$\frac{E_{1peak}}{E_{2peak}} = \frac{BW1}{BW2} \text{ or,} \qquad (2a)$$

$$\Delta E\ (dB) = 20 \log \frac{BW1}{BW2}\ dB \qquad (2b)$$

significance of different bandwidths

Here, the question of RF preselection (input RF bandwidth) comes into play. If no preselection exists (as in the case with a spectrum analyzer), the measured output levels (analyzer and receiver) are different. Assume you are testing in the 30-1000 MHz range. Typical input filter bandwidths are

measuring receiver	$BW1 = 30\ MHz$
spectrum analyzer	$BW1 = 1800\ MHz$

Consequently, the voltage E1 presented to the first mixer of the device is 48 dB and 83.5 dB higher, respectively, than the output (indicated) voltage E2. Therefore, the narrower RF filter of the measuring receiver lowers the required mixer dynamic range by 35.5 dB (83.5 − 48 = 35.5).

Let us apply these facts to the measuring receiver and spectrum analyzer. We have assumed that each device uses the same mixer (with equal maximum input voltages), and the receiver has an approximately 10 dB lower noise figure. (This is typical, though the difference may even be greater, as in **fig. 3**.)

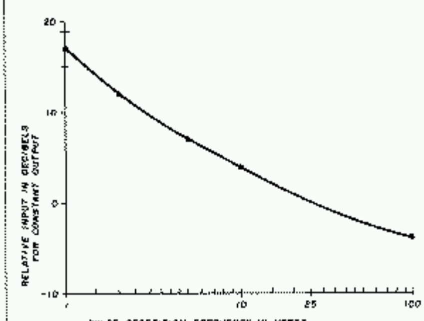

fig. 4. Pulse response curve for the frequency range 10 kHz to 150 kHz (per CISPR Publication No. 16, 1977).

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Therefore, one can see that when making "peak" measurements with a spectrum analyzer the usable dynamic range is so limited that the measurement must be monitored carefully to assure the linear operation of the mixer. This can be accomplished by switching in a small amount of attenuation and comparing this value to the drop in measured output. However, this is time-consuming, and definitely not in line with the requirements for rapid automated testing.

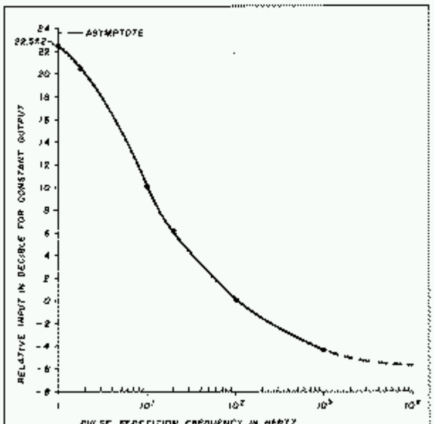


fig. 5. Pulse response curve for the frequency range 150 kHz to 30 MHz (per CISPR Publication No. 16, 1977).

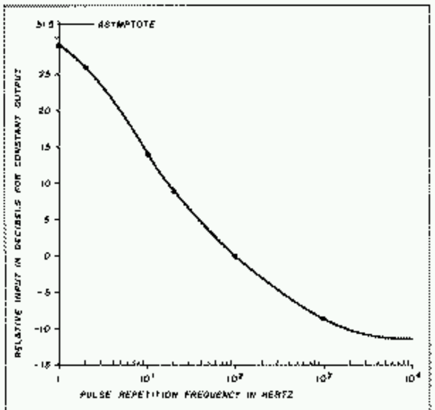


fig. 6. Pulse response curve for the frequency range 30 MHz to 1000 MHz (per CISPR Publication No. 16, 1977).

problem with quasi-peak detectors

The most serious flaw in the application of spectrum analyzers is in the use of a "quasi-peak" detector. A "quasi-peak" detector is simply a weighting network that gives a weighted indication based on the PRF (pulse repetition frequency) of the incoming pulse spectrum. (The curves for this weighting are shown in **figs. 4, 5, and 6**). The variation in weighting in the VHF/UHF range is 39.5 dB. It is impossible for a measuring device with a usable dynamic range of only 7.5 dB to give a correctly weighted output over a 39.5 dB range. (Remember, the weighting circuitry is at the IF, **after** the "damage" is done.)

The final conclusion is that, based on the simple physics of the measurement, it is difficult to measure pulse spectra peaks with a spectrum analyzer, and the use of "quasi-peak" circuitry at the IF of an analyzer is impossible without appropriate RF preselection. (**Fig. 7** shows overall selectivity as a function of frequency range required for the EMI/RFI test receiver to meet specifications.)

high-dynamic range required

Fig. 8 shows the block diagram of a modern RFI test receiver. It consists of an RF attenuator, a built-in calibrator, a tracking input filter, a mixer, IF stages, and the detector for demodulation, as well as the required weighting filter and rectifiers.

It becomes immediately apparent that the major difference between this block diagram and the block diagram of a typical communication receiver is the RF attenuator, the calibrator, and the lack of preamplification ahead of the mixer.

Assume that a high level double-balanced mixer is used, and that both the RF attenuator and the bandpass filter do not introduce any intermodulation distortion. In this case, the large signal performance of the receiver is determined by the mixer and the stage immediately following the mixer, most likely a termination amplifier with a crystal filter immediately following it.

The mixer, typically a passive device, introduces 5.5 to 6 dB of loss to the next stage (an amplifier). Most likely, these two stages determine the overall intermodulation distortion performance of the receiver. The high level double balanced mixer and the post-amplifier probably have a +30 dBm intercept point.

The presence of the input filter not only reduces the number of signals but also improves the second order intermodulation distortion substantially, relative to a wide-open front end.

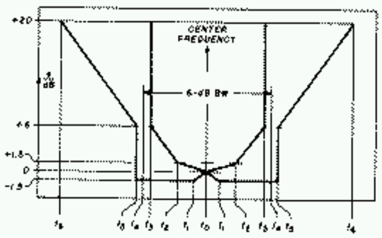
prevention of overload

The receiver can saturate if the combined signal level present at the output of the input tracking and IF crystal filters is excessive. While it may not be possible to prevent such an overload condition initially, it is important to detect the condition. The input RF attenuator can then be used to reduce the overload.

The automatic and computer controllable EMI/RFI receiver ESH3 automatically switches in the required attenuation to make sure that this overload condition does not occur while providing a 60 dB dynamic range at the IF.

The microprocessor-controlled receiver has its own intelligence and combines the proper RF and IF attenuation for optimum dynamic range. It is theoretically possible to increase the IF attenuation rather than the RF attenuation. As in the manually operated receiver, the two functions are not tied together, and the inexperienced operator may not be aware that the intermodulation distortion products can only be reduced by using the RF attenuator.

In order to monitor the actual overload, special detectors are placed after the mixers, because modern receivers use a first IF approximately twice the maximum receiving frequency, the first IF of the test receivers can be expected to be in the vicinity of 70 to 80 MHz. The second IF is then substantially lower (between 9 and 11 MHz), depending upon the receiver, and sometimes even a third IF (30 kHz) for the very narrow bandwidth requirements is used. This design requires two monitoring stages after the mixers to make sure no overload occurs.



RF RANGE MHz	MIN	0.010	0.15	30	MHz
	MAX	0.150	30	1000	MHz
$f_1 = f_0 \pm$		0.08	1	10	kHz
$f_2 = f_0 \pm$		0.05	2	20	kHz
$f_3 = f_0 \pm$		0.045	4	50	kHz
$f_4 = f_0 \pm$		0.1	4.5	60	kHz
$f_5 = f_0 \pm$		0.11	5	70	kHz
$f_6 = f_0 \pm$		0.22	10	140	kHz

fig. 7. Required selectivity of the EMI/RFI receiver as a function of frequency range.

time constants

EMI receivers are also distinguished by specific values of detector attack and decay time constants, with typical values being 1 and 160 milliseconds, respectively, in the 0.15-30 MHz frequency range. A good communications receiver uses totally different time constants. In the SSB/CW mode, the attack time would probably vary between 3 and 15 mS, depending upon the manufacturer, and the discharge time constant would be in the vicinity of 200 mS to 10 seconds selectable. The 1 mS attack time for the pulse receiver is too fast and will result in a "quasi-peak" reading, which for the EMI receiver is desirable

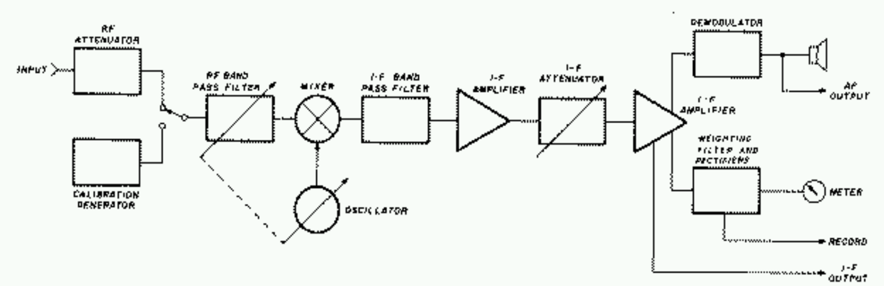


fig. 8. Block diagram of an EMI/RFI receiver.

but would lock up the AGC in a communication receiver each time an unwanted noise spike occurred.

Some manufacturers have chosen to make the EMI/RFI receivers more universal by adding built-in detectors for the communication mode as well. The ESH2 and ESH3 have this flexibility.

IF bandwidth

Special IF bandwidths are needed in EMI/RFI receivers; 200 Hz is chosen for the lowest frequency range (10 kHz-150 kHz) 9 kHz for 0.15-30 MHz and 120 kHz for 30-1000 MHz.

At 200 Hz, the bandwidth for the frequency range of 10 kHz to 150 kHz almost requires a triple conversion receiver in order to obtain narrow bandwidth with a good shape factor.

At 30 kHz, the 200 Hz bandwidth filter is more likely a mechanical filter than a crystal filter, as the cost otherwise would be prohibitive.

amplitude calibration

There are two ways to calibrate the receiver. One is to use a pulse generator, such as the ones manufactured by Schwarzbeck, (models IGM 2913, 10 kHz to 30 MHz, and IGU 2912, 25 MHz to 1000 MHz) which operate over a fairly wide pulse rate. With a calibrating pulse of 0.316 microvolts per second and a repetition frequency of 100 Hz, the frequency range of 150 kHz to 30 MHz can be covered. The particular calibration voltage should give a 0 dB reading on the meter.

Sine wave calibration is also possible. This requires a second generator which can be provided inside the instrument. The sine wave output is a good cross-reference for the calibration of the pulse generator.[2] As the calibration of the instrument depends upon these signal sources, it is important that these signal sources be built in such a way that aging effects, temperature, and voltage variations do not affect them. Modern special feedback circuits can solve this problem.

In the case of automated receivers, like Rohde & Schwarz ESH3, the built-in microprocessor, together with the random access memory, allows the development of a scanning program in which the receiver is calibrated over the entire frequency range, and the actual error is stored in memory. As measurements are made, the receiver uses a "look-up" table to add the correction factor. This is convenient because the operator does not have to worry about the accuracy of the receiver.

A manually operated receiver has to be calibrated for each major frequency change, which can be time-consuming since the values also have to be written down for future use. A word of caution: it should be remembered that the frequency synthesizer also is an

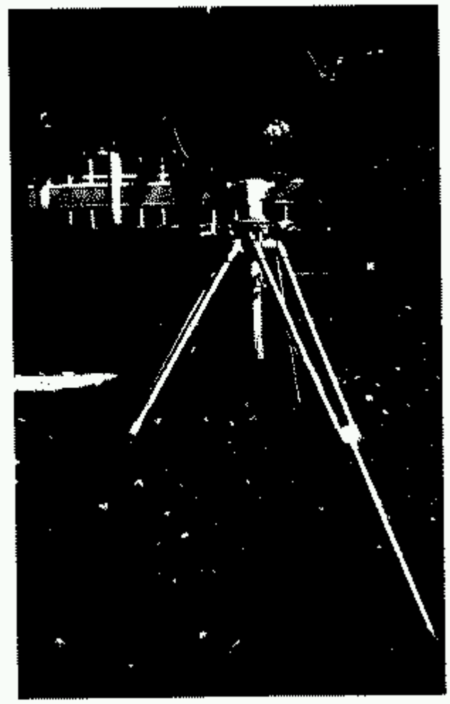


fig. 9. Loop antenna system recommended for EMI/RFI testing.

important factor in receiver performance. The noise sideband of the synthesizer and its inherent spurious performance have to be good enough to prevent any spurious frequencies or sidebands from appearing and giving erroneous readings. Therefore, the reference suppression and all mixing products have to be suppressed sufficiently.

antennas

The use of tuned antennas is rare at lower frequencies (between 10 kHz and 150 kHz). In this frequency range it is better to use loop antennas or active antennas. Again, it is important to make sure that the dynamic range of the active antennas are sufficient. While the test site has to be properly designed and reflections have to be avoided it should be mentioned here that if an active antenna is used, its dynamic range must be sufficient.

For frequencies above 20 or 30 MHz, reference dipoles or logarithmic periodic antennas may be used, depending upon the particular frequency. It would be best to look up the particular recommendations and requirements by CISPR and VDE/FTZ. (To measure conducted interference, current probes and absorbing clamps can be connected to the receiver, but this will not be discussed here, since this article is limited to discussion of the receiver itself.)

Fig. 9 shows a loop antenna; **fig. 10** shows an active rod antenna; **fig. 11** shows a log-periodic antenna for VHF/UHF.

conclusion

The EMI/RFI receiver is a more sophisticated and, therefore, more expensive receiver than standard communication receivers. While it is possible to incorporate features to make the reception of communication transmission possible, which is useful for signal identification, then overall accuracy, special pulse response behavior, and the necessary preselector make the receiver more complicated and, thus more expensive. EMI/RFI receivers should be offered in both manual and automated versions to fit varying budgets. However, if large quantities of data must be handled, the automated version is the more logical choice.

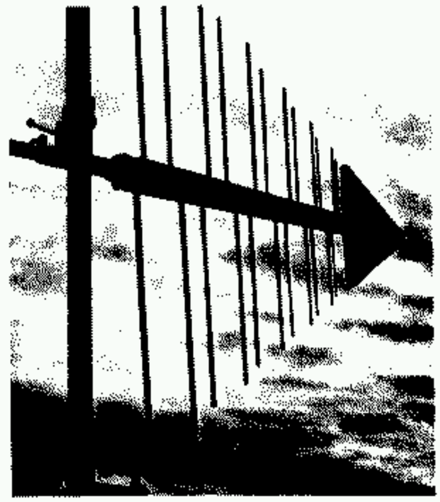


fig. 11. Logarithmic periodic antenna for EMI/RFI testing up to 1000 MHz.

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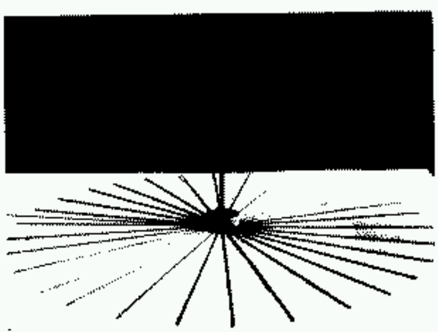

fig. 10. Rod antenna recommended for EMI/RFI testing for frequency range up to 30 MHz.

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