UP/DOWN CONVERTER FOR SCPC APPLICATIONS

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ABSTRACT

A compact 6/4 GHz Up/Down converter has been developed specifically for single channel per carrier(SCPC) satellite communications. For operation at remote locations where elaborate instrumentation and skilled personnel are generally not available high reliability and low down time are the prime objectives. These are achieved through extensive use of modular construction and built-in diagnostics employing proven technology.

INTRODUCTION

For remote earth stations with traffic requirements of only a few voice channels, the SCPC mode of operation provides one of the most cost-effective and optimum solutions. The SCPC channels may use either Analog (FM) or Digital (PSK) modulation. The Up/Down converters used for FDM-FM and TV carriers are not suitable for this due to limitations of close-to-carrier phase noise and frequency stability. The special features of an up/down converter developed for SCPC use are presented. Although primarily developed for use with the Indian domestic satellite INSAT (1), it can also be used with the INTELSAT and other similar satellites, as it meets all the relevant specifications.

SYSTEM CONFIGURATION

The Up-Converter accepts a composite

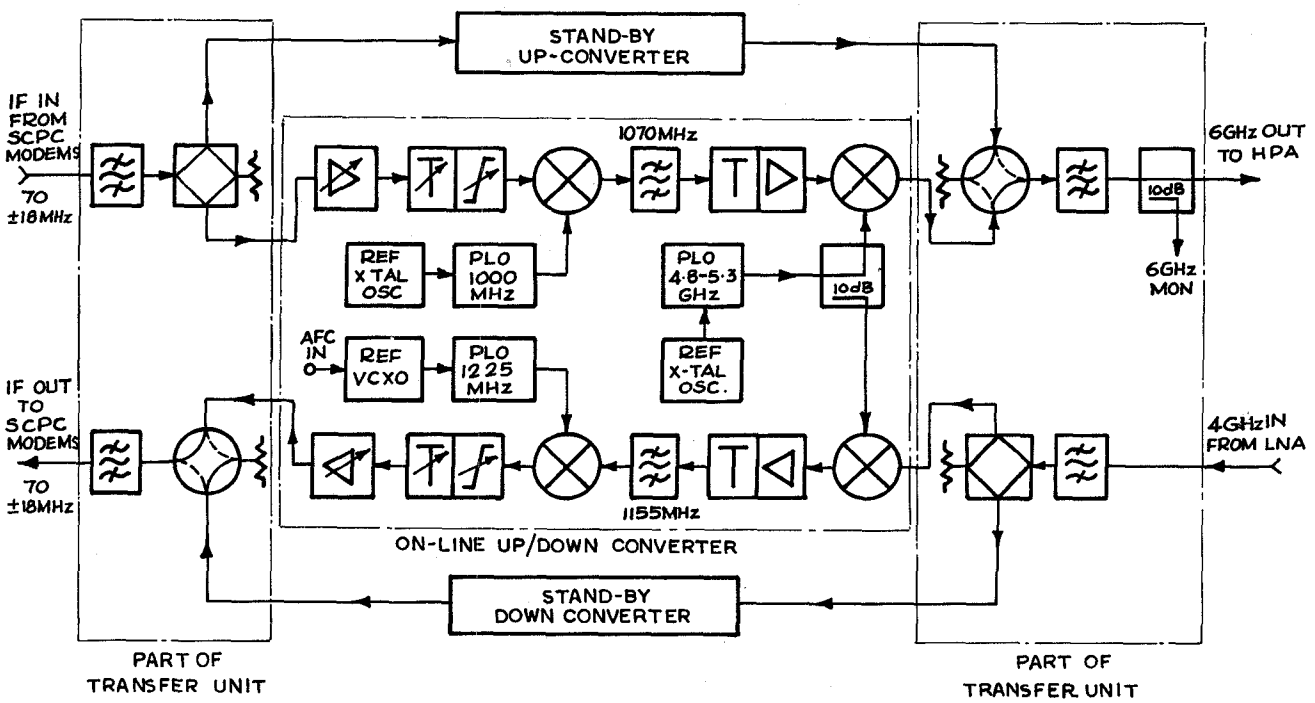

Fig.1 Block Schematic of a dual-redundant up/down converter

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input signal of multiple SCPC carriers from SCPC modulators (normally spaced 22.5, 30 or 45 KHz apart) in the 70 ± 18 MHz band and gives an output in the assigned transponder in the 5925- 6425 MHz band. The down-converter selects the transponder of interest and converts the carriers to the 70 ± 18 MHz range for driving the SCPC demodulators. Dual conversion is used both in Up and Down converters to provide frequency agility and to facilitate selection of any transponder with minimal change.

A unique aspect of the SCPC scheme (as different from those for FDM-FM or TV-FM carriers) is that the same transponder is used for transmit as well as receive channels. It is therefore possible to use a common local oscillator for both up and down conversion by suitably choosing the intermediate frequencies (IF) on the transmit and receive sides so that they add up to 2225 MHz. It is also preferable to select the two IFs to be of the same order (but not identical so asto avoid problems of direct pick-ups from transmit to receive path) so that similar amplifiers and filters can be used in both directions. With this in view, 1070 MHz and 1155 MHz are chosen as the IFs as this particular combination results in minimal in-band intermodulation products. The common local oscillator (LO) is tunable over the 4855-5355 MHz band to cover all transponders. To avoid spectral inversion, 1000 MHz and 1225 MHz are chosen as the other two LO frequencies.

Fig.1 shows the block schematic of a dual-redundant up/down converter. The band-pass filters (BPF) at 70 MHz, 6 GHz and 4 GHz are totally passive circuits and need no redundancy. Hence only one set of these is used in a common transfer unit which continuously monitors the status of both converters and in the event of a failure in the on-line one,automatically switches over. Manual override facility for maintenance purpose is also provided.

DESIGN CONSIDERATIONS

For operation with SCPC systems, some special design considerations apply. The adjacent channels are typically spaced 22.5 to 45 KHz apart, while the baseband (voice) signal occupies 0.3 to 3.4 KHz band. Hence all the LOs need have high frequency stability and extremely low phase noise for offsets of 300 Hz and above. In-band noise performance as also frequency stability requirements are met by using low noise high-stability oven-controlled crystal oscillators around 100 MHz to which the microwave oscillators are phase-locked. The latter employ mechanical tuning with high-Q resonators so as not to adversely affect noise performance in other channels. Microwave freuency synthesizers commonly used for FDM-FM signals cannot be used owing to their higher FM noise.

Due to the presence of a large number of SCPC carriers special care has to be taken to limit the intermodulation products to acceptable levels. Double-balanced mixers with high third-order intercept points and highly linear amplifiers are used throughout to achieve this.

In order to meet the specification on transmitted spurii levels, the 70 MHz BPF in particular as also the 1070 MHz and 6 GHz BPFs need have very sharp selectivity. This is achieved by using an elliptic function LC filter at 70 MHz and inter-digital Tchebyscheff design for the other two.

An amplitude equaliser is provided at 70 MHz on both up and down converters to compensate for amplitude frequency response. Correction of both linear (positive and negative) and parabolic responses is possible.

AUTOMATIC FREQUENCY CONTROL (AFC)

As the SCPC carriers are very closely spaced, the frequency drifts

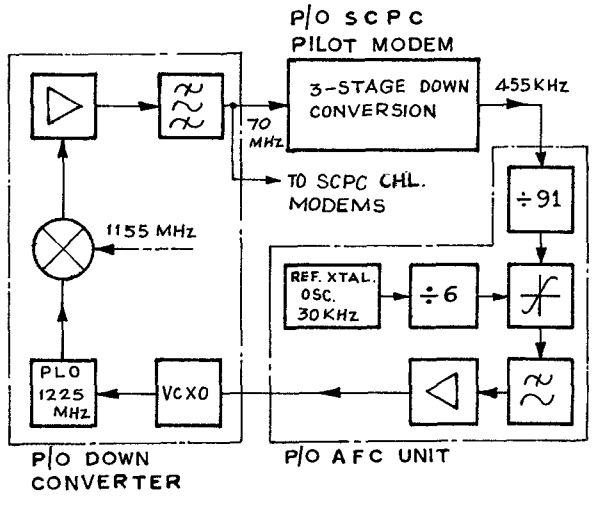

Fig.2 Scheme for AFC operation.

introduced by the satellite transponder local oscillators and the doppler frequency shift can be serious problems if left uncorrected. In order to overcome this, one of the SCPC stations constantly transmits a pilot which is used for AFC at the receive stations.

The AFC scheme is shown in Fig.2 One of the outputs from the down converter is fed to a pilot demodulator wherein the 70 MHz pilot is down converted to 455 KHz in three stages. This 455 KHz signal and a reference 30 KHz signal are then compared in a phase detector after suitable frequency divisions. The error output after proper filtering and amplification is given as an AFC voltages that controls the frequency of the reference VCXO (voltage controlled crystal oscillator) to which the 1225 MHz LO is phase-locked. Thus any drift present in the received pilot signal at 4 GHz corrects the 1225 MHz LO frequency such that the entire down-converted spectrum is shifted till the pilot at 70 MHz is correctly centered. As the 30 KHz signal is derived from the high-stability main reference oscillator, the AFC corrects any drift present to the accuracy of this reference. The AFC loop filter bandwidth is kept sufficiently low to enable the use of modulation on the pilot modem as any modulation present is filtered out and does not effect the AFC operation. A manual frequency control mode of operation is also provided.

PERFORMANCE CHARACTERISTICS

The major performance data of the up/down converter is given in Table I.

As most of the SCPC earth stations are in remote locations with poor accessibility,the equipment must have a very high degree of reliability. This is achieved by using proven technology and conservative designs for the overall system as well as individual units. All components and sub-systems used are rated for an extended environmental range. Although normally intended to operate in an air-conditioned environment, the equipment can operate over the range of 0^{o} to 50^{o} C with upto 95% relative humidity at 40^{o} C.

Another important needis that in the event ofafailure, the down time should be an absolute minimum. Extensive use is made of visual alarms and several dc and rf test points are provided for quick diagnostics. A summary alarm is available for remote extension. All the units use modular plug-in construction to facilitate easy maintenance.

The dual redundant up-down converter sub-system consisting of two up-down convertors and a transfer unit is housed in a standard 19" EIA rack occupying 8 3/4 " height. The two up/down converters are each powered by an independent power supply unit, while the transfer unit is powered by both in parallel. A photograph of the dual-redundant up/down converter is shown in Fig.3

Table-I Major Performance Data of Up/ Down Converter.

IF Band	: 52 to 88 MHz
IF level per chl	: -45 dBm at up-converter input -18 dBm at down-converter output
RF Band	: Any transponder in 5925-6425 MHz/3700-4200 MHz band
RF Level per chl	: -30 dBm at 6GHz output -75 dBm at 4GHz input
Amplitude response	: 0.5dB p-p over any 36 MHz band
LO frequency stability	: 1 x 10^{-9} per day
FM noise	: -75 dB-Hz for 0.3 to 3.4KHz offset
Two-tone inter-modulation	: better than -60dBc with each tone at nominal level
Spurious outputs	: better than -50dBc in any 4KHz band at 6 GHz
Image rejection	: better than 80 dB
Noise figure of down converter	: 15 dB max.

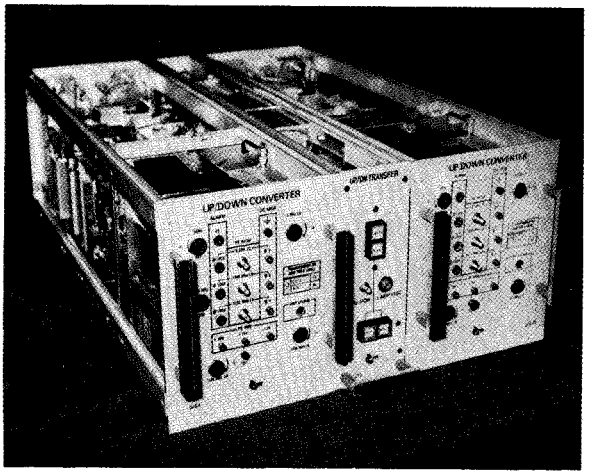

Fig.3. Photograph of dual-redundant up/down-converter.

CONCLUSIONS

The equipment has been indigenously developed and employed for both FM-SCPC and PCM-PSK-SCPC applications. For the Indian domestic satellite network using INSAT-I satellites nearly 40 up/down converters have been in operational use since 1981, in static inland and off-shore as well as transportable earth stations. Their performance is fully satisfactory with very low down-time. Certain local heating problems were noticed in the high power phase-locked oscillators and forced air cooling is being incorporated to improve the reliability further.

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REFERENCE

(1) S.Dhawan et al, "INSAT-I A Multipurpose Domestic Satellite System for India", IEEE Trans.on Broadcasting, Vol.BC-25,4,pp.121-127: Dec.1979.